Caries decline before fluoride toothpaste was available: earlier and greater decline in the rural north than in southwestern Norway

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Birkeland JM, Haugejorden O. Caries decline before fluoride toothpaste was available: earlier and greater decline in the rural north than in southwestern Norway. Acta Odontol 2001;59:7–13. Oslo. ISSN 0001-6357.

The purpose of this study was to evaluate factors related to caries in 6–17-year-olds in 2 groups of Norwegian counties between 1966 and 1983. The average number of surfaces filled and permanent teeth extracted due to caries declined in the 4 northern counties from 1967. An increase was recorded in the 7 southwestern counties until 1971, then a decline. In the 1960s significantly more surfaces were filled and teeth extracted in the north compared to the southwest. Based on intra-county comparisons, the decline in surfaces treated was greater in the north between 1967 and 1983; 5.4 ± 0.4 vs 3.7 ± 0.7, $P < 0.01$. The averages were 1.9 surfaces treated in the north and the southwest in 1983. Higher infant mortality, lower percentage of people with completed senior secondary education, and more inhabitants per doctor and per dentist in the north indicate a less favorable situation than in the southwest. School-based fluoride programs had been implemented in both groups from the mid-1960s and around 60% participated when fluoride toothpaste became freely marketed in 1971. More fluoride programs and more fluoride tablets were available to children in the north; this may indicate a preventive attitude among dentists. The decline of caries started at different times in different parts of Norway. In the rural north with the most unfavorable situation, the decline was greater and started years before fluoride toothpaste came on to the market. The early decline may partly be ascribed to the school-based fluoride programs, the continued decline to several factors. □ *Children; county; dental care; education; fluorides*

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Scientists differ in opinion when it comes to ranking the factors responsible for the decline of caries in industrialized countries during recent decades. Most experts consider fluoride toothpaste to have been a very important factor in this (1). A review of the reviews from 6 international conferences during the last 2 decades shows the complexity of the issue, but fluoride in various forms seems to be the main reason for the decline (2). Opinions also differ as to the reasons for the marked improvement in the oral health of young Norwegians (3–8). The caries decline in Norway is claimed by some to have occurred simultaneously throughout the country, and to have been caused by fluoride toothpaste (6), but no statistical analyses have been presented in support of the claim.

In planning future caries prevention, it is important to know the impact of different caries controlling factors (1). Krasse (9) considered the effect of fluoride toothpaste to be overrated, and this view is supported by findings from Iceland (10) and Japan (11). A few studies relate the decline statistically to toothpaste (3, 12, 13). In one study, simple but not multiple regression analyses indicated a significant effect of fluoride toothpaste (13). Most studies indicating caries decline have been based on time trend analyses. There is therefore a general lack of statistical assessment of factors associated with caries decline in the Western world. The introduction of the Norwegian Public Dental Services facilitates a comparative approach to the assessment of factors related to caries decline. The purpose of this study was to re-evaluate the caries situation in different parts of Norway and to try to assess the possible effect of some factors related to the decline.

Materials and methods

County groups and dental care

Since the 1950s, there have been 2 public systems providing free dental care to children and adolescents, i.e. the School Dental Service (SDS) and the Public Dental Service (PDS). Because of a very unfavorable distribution of dentists in the north and in rural areas since the Second World War, the PDS was first implemented in the north. Being more comprehensive, the PDS was gradually implemented in all counties and in 1984 replaced the SDS, which included children aged 7–15 years compared to 6–17 years in the PDS.

This study covers counties where the PDS had been implemented by 1966. Fulfilling this requirement, 2 groups were formed: one comprising the 4 most northern, the other the 7 southwestern counties along the coast. In the southwest the PDS generally replaced the SDS.

Data related to children 6–17 years of age and served by the PDS during the period 1966–83 were reported annually. Gradually more children received comprehensive dental treatment (Table 1). The national age-specific treatment rate increased during the 1970s, especially for the 6-year-olds and the oldest children: 6 years, 67%–

89%; 7–15 years, 85%–93%; 16–17 years, 54%–82% (14, 15). Most of these children were included in the two county groups. A heavy workload and the strictly incremental care approach starting with the youngest children at the beginning of each calendar year may explain the lower treatment rate for the oldest age group. In the early 1970s the treatment rate was of the same order of magnitude in both groups of counties (Table 1).

The aggregate county average number of surfaces filled in permanent teeth for the 12 age groups 6–17 years was reported for the period 1966 to 1983 (14, 15). Surfaces were filled owing to primary or recurrent caries as well as because of replacement or extension of fillings. Besides surfaces filled, teeth extracted due to caries or for other reasons, and the number of root-filled teeth were reported. There should be no differences in the treatment criteria between counties.

The original sources of information regarding dental care were the public dental records. The weighted county data do not allow individual data, nor do they permit age-specific analyses. Furthermore, the official reports give no information about diet, oral hygiene, or preventive dental care.

Table 1. Some characteristics of the 4 northern and 7 southwestern Norwegian counties during the period 1966–1983

Variables (year/period)	North	Southwest
Public Dental Service implemented	1950–57	1958–64
No. of children 6–17 years treated		
1966	66,394	61,275
1968	61,905	74,663
1970	74,230	81,005
1972	92,614	110,503
1974	105,416	140,338
1980	114,905	211,108
1983	111,065	234,563
Percentage 6–17-year-olds treated		
1972	71–85	59–95[1]
1974	81–91	82–97
1980	90–94	86–96
Inhabitants per dentist		
1968	2,063[2]	1,598[3]
1973	1,739	1,353[3]
1978	1,391	1,131[3]
Inhabitants per doctor		
1968	1,241	1,058[2]
1973	799	764
1978	662	642
Percentage 20 yr and older with senior secondary education		
1970	11.8	13.9[2]
1975	22.6	26.6
1980	28.5	31.5
Infant mortality/1,000		
1966–70	15.7	13.6[2]
1971–75	13.4	11.4
1976–80	9.8	8.9

[1] Range for counties. [2] Average for counties. [3] Significant; $P < 0.05$.

Background information

Census data from official statistics on infant mortality and the percentage of subjects 20 years and older with senior secondary education indicate a less favorable socio-economic level in the north (Table 1) (16). The proportion who completed senior secondary education, termed education, increased similarly in both groups of counties. Education is positively related to improved oral health (17) by a more positive attitude regarding consumption of 'sweets', the use of fluorides and oral hygiene devices. The ratio of inhabitants per doctor and per dentist, as well as the infant mortality, improved in both groups of counties during the 1970s (Table 1). Both groups of counties had more inhabitants per dentist than the average for the country; 1244 in 1968 and 1085 in 1973 (16). Some county data were not reported annually.

Sodium fluoride tablets containing 0.25 mg fluoride could be prescribed from 1963. The yearly sale of fluoride tablets is defined as daily doses per 1,000 inhabitants (DDD/1,000) below 15 years of age (18). The sale corresponded to use by 1% of children below 15 years of age in 1971 (19). Sales increased until 1977 (Fig. 1) (18). Primarily, chewable lozenges were used and data indicate about twice as frequent use by children before as after 6 years of age (20). County data for fluoride tablets were only available for 1976, 1977, 1979, 1981, and 1983. In the north, significantly more tablets were sold in 1976 ($P = 0.002$) and during the period 1976–83 ($P = 0.026$).

Based on available information, supervised fluoride mouth-rinsing fortnightly and tooth-brushing programs 4–5 times a year for children 7–14 years of age were implemented in the 1960s and 1970s, reaching 71% and 88% of the children in the southwest and north, respectively (Fig. 1) (21). Data for the counties were only available from 1967 to 1976 (21). There was no significant difference in the participation rate between the groups in 1967 ($P > 0.14$).

Toothpaste with 0.1% fluoride could be prescribed from 1969. It was released for over-the-counter sale in September 1971 and constituted between 50% and 60% of total sales of toothpaste in the early 1970s (Fig. 1) (Colgate Palmolive, pers. comm., 1997).

The consumption of 'sweets' adjusted for import and export increased continually between 1960 and 1983 from 4.6 kg to 11.4 kg per capita. The increase was primarily related to chocolate. People were advised to reduce their intake of 'sweets', but the effect of the advice is unknown. Despite the increasing consumption of 'sweets', the total annual consumption of sugar remained about 42 kg per capita during the period 1960 to 1983. County data are not available on consumption of 'sweets' nor on the sale of fluoride toothpaste.

Analyses

In order to reduce the effect of yearly variations in the reported data, 2-year moving averages were employed for surfaces filled (1966/67 = 1966) and for the school-based fluoride programs. Teeth extracted due to caries were

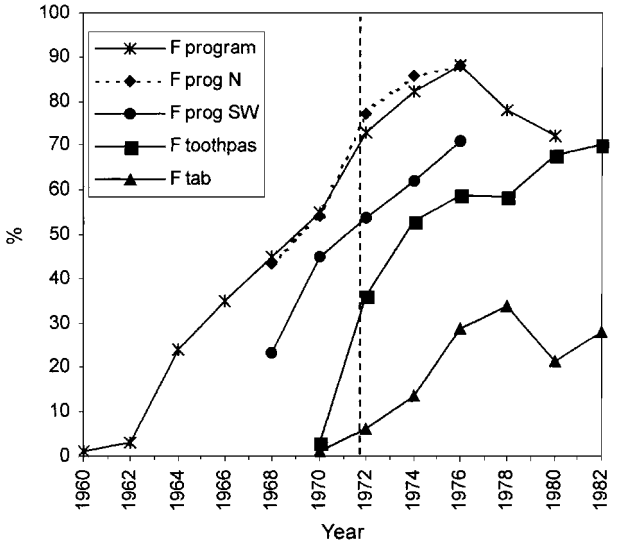

Fig. 1. Nationwide sale of fluoride tablets in DDD/100 children under 15 years; percentage of fluoride toothpaste of total toothpaste sale, and percentage of schoolchildren aged 7–14 years participating in school-based fluoride programs by year. Participation (%) in school-based fluoride programs in 4 northern and 7 southwestern counties according to year. Dotted line indicates September 1971 and the release of fluoride toothpaste on to the market. Data are related to the end of a calendar year; December 1967 = 1968, etc.

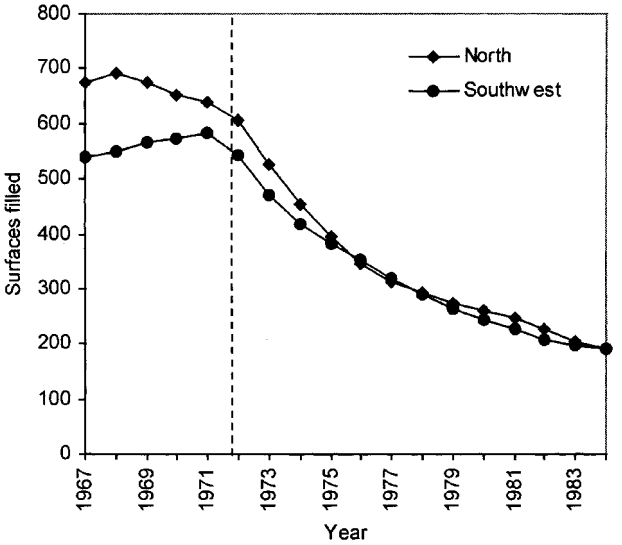

Fig. 2. Aggregated average number of tooth surfaces filled per 100 children 6–17 years for the 4 northern and the 7 southwestern counties by year. Dotted line indicates September 1971 and the release of fluoride toothpaste on to the market. Data are related to the end of a calendar year; December 1966 = 1967, etc.

counted as 3 surfaces filled. Added to surfaces filled, this sum was termed 'surfaces treated'.

Cross-sectional comparison between the 2 groups was assessed using Student's *t* test. Within-county comparisons were carried out for dental variables as well as other variables. In these quasi-longitudinal paired comparisons the calendar year 1967 was generally taken as the baseline for the dental variables. Corresponding baseline for the other variables depended on when the information first became available, as indicated in Table 1. In order to assess when a decline in caries occurred, the number of surfaces treated was either regressed (cubic regression) on the 5 calendar years 1967–71 or longer periods, such as 1967–75.

Within-county time-related changes (baseline minus later data) in surfaces treated for the periods 1967–75 and 1967–83 were related to the background variables or changes in these variables (Table 1) using bivariate (Spearman's rho) and partial correlation analyses. The shorter period was chosen owing to the availability of data concerning the fluoride programs in the counties and to relate changes to the period of the free marketing of fluoride toothpaste. Because of the small sample size, the multivariate analyses were restricted to the longer periods of observation and a maximum of 3 independent variables.

Since the data are aggregated, statistical significance tests should be interpreted with caution. A P value of 0.05 indicates significance for data related to the counties; a P value of 0.01 was used for the dental variables.

Results

Dental treatment

The lines representing the average number of surfaces filled for 6–17-year-olds showed different profiles in the north and southwest during the late 1960s (Fig. 2). A decline was evident in the north after 1967, from 1971/72 in the other counties. The number of surfaces filled had decreased to 1.9 in both areas by 1983.

The number of permanent teeth extracted due to caries decreased in the late 1960s (Fig. 3). Although the rate of extraction tended to be highest in the north in the 1960s, there was no significant difference between the 2 groups ($P = 0.062$; 1966). When teeth extracted as a result of caries were added to the number of surfaces filled, significantly more surfaces had been treated in the north than in southwest during the 1960s (Table 2). Whether the analyses were based on surfaces filled or treated affected only the 1969 comparison. The P value decreased from 0.018 to 0.009 for surfaces treated.

Regression analyses between the number of surfaces filled or treated and the 5 calendar years 1967–71 showed a significant negative slope in curvilinear analyses for the northern counties ($P = 0.001$). For the southwestern counties the regression coefficient was insignificant until the year 1975 was included, $P = 0.002$ vs $P = 0.015$ in 1974.

Within-county comparisons confirmed no decline in treatment in the southwest until 1971 (Table 3). Significantly different declines in the 2 groups of counties

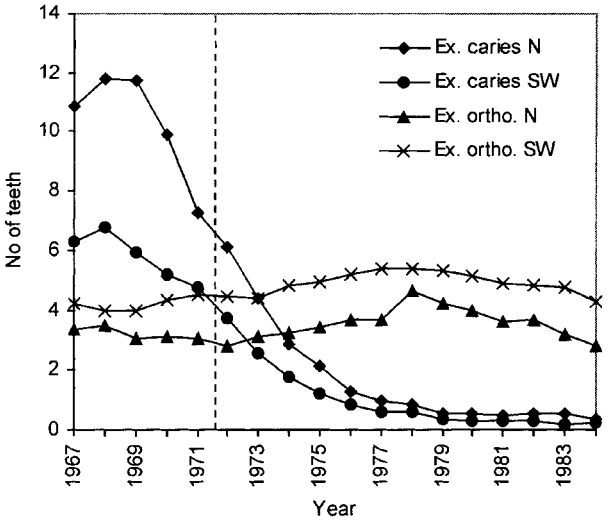

Fig. 3. Aggregated average number of permanent teeth extracted due to caries or other reasons per 100 children 6–17 years for the 4 northern and the 7 southwestern counties by year. Dotted line indicates September 1971 and the release of fluoride toothpaste on to the market. Data are related to the end of a calendar year; December 1966 = 1967, etc.

were recorded when data for 1974 and the following years were included; the decline was greater in the north.

Neither the number of permanent teeth extracted for reasons other than caries (Fig. 3) nor the number of root-filled teeth were significantly different in the 2 groups ($P > 0.01$). The extractions for other reasons remained at about the same level in the north and in the southwest (Fig. 3). The number of root-filled teeth declined to the same level in both groups; from 1.0 to 0.4 per 100 children per year.

Factors associated with the decline

Bivariate correlation analyses based on short or long periods of observation gave similar findings (Table 4). The only association found to be significant at the 1% level was between sales of fluoride tablets and the decline in

Table 2. Sum of surfaces filled and permanent teeth extracted due to caries[1] in 6–17-year-olds by group of counties and year of treatment

Year	Groups of counties	
	North ($n = 4$)	Southwest ($n = 7$)
1967	7.3 ± 0.24[2]	5.6 ± 0.70[3]
1969	6.8 ± 0.46	5.9 ± 0.44[3]
1971	6.2 ± 0.32	5.6 ± 0.57
1975	3.5 ± 0.44	3.5 ± 0.34

[1] Extracted teeth equal to 3 surfaces filled. [2] Mean and standard deviation. [3] Significant; $P < 0.01$.

Table 3. Sum of surfaces filled and permanent teeth extracted due to caries[1] in 6–17-year-olds by group of counties and years of comparison[2]

Years	Groups of counties	
	North ($n = 4$)	Southwest ($n = 7$)
1967–71	1.1 ± 0.42	-0.1 ± 0.71[3]
1967–73	2.5 ± 0.55	1.3 ± 0.81
1967–74	3.3 ± 0.69	1.7 ± 0.78[4]
1967–75	3.8 ± 0.66	2.0 ± 0.88[4]
1967–83	5.4 ± 0.40	3.7 ± 0.70[4]

[1] Extracted teeth equal to 3 surfaces filled. [2] Paired comparison within counties; baseline the year 1967. [3] Mean and standard deviation. [4] Significant; $P < 0.01$.

treatment provided. However, P values < 0.05 were observed for the variables: inhabitants per dentist in 1978, year of implementation of PDS, the school-based fluoride programs in some years (1967, 1968, 1971–76), and the proportion with senior secondary education in 1975 (Table 4). The ratio of inhabitants per dentist for 1978 alone indicated significance in the correlation analyses.

When variation in a background variable over time was related to the treatment changes, only fluoride tablets tended to be significantly ($P = 0.021$ and 0.033) associated with caries decline (Table 4). Owing to parallel changes in the different independent variables in the counties, the changes were less indicative of a relationship than data for specific years.

Partial correlation analyses based on the variables with $P < 0.05$ in the bivariate analyses showed that only fluoride tablets had a significant effect at the 1% level. The P values at the 5% level depended on variables included in or excluded from the analyses (Table 5); only the fluoride variables tended to show effect. Multiple regression analyses indicated no significant effect of any predictor; the smallest P value being 0.15.

Discussion

Methodological comments

The number of fillings inserted and permanent teeth extracted owing to caries was used to reflect caries activity. All lesions in permanent teeth requiring a filling were assumed to be treated. Analyses have shown better agreement between surfaces filled and the DMFS increment for children with low compared to high caries incidence owing to less replacement of fillings at low caries activity (22). Moreover, 83% of the DMFS scores in 13-year-old Norwegians were filled surfaces in the early 1970s (23). A 70% decrease in the number of surfaces filled was found to be equivalent to 50% reduction of DMFS at age 14 years (24).

Table 4. Spearman's rho and *P* values (in italic) between background variables and the average decline in sum of number of surfaces filled and permanent teeth extracted due to caries[1] in 6–17-year-olds by counties and years of comparison[2]

Years	Public care implemented	Inhabitants/ dentist 1978	Education 1975	F-programs 1972	F-tablets 1976	F-tablets 1976–83
1967–75	0.66	0.64	−0.62	0.70	0.82	0.68
	0.026	*0.035*	*0.042*	*0.016*	*0.002*	*0.021*
1967–83	0.75	0.65	−0.62	0.68	0.82	0.64
	0.008	*0.030*	*0.042*	*0.022*	*0.002*	*0.033*

[1] Extracted teeth equal to 3 surfaces filled. [2] Paired comparison within counties ($n = 11$); baseline the year 1967.

Extraction of permanent teeth because of caries reflects serious destruction. Accordingly, and since most of the extracted teeth are likely to be molars or premolars, they were counted as 3 surfaces filled. Whether extracted teeth were included or excluded had minor impact on the variation, and hence the results. Including the extracted teeth decreased the *P* values slightly, and the difference became significant in 1969 ($P = 0.018$ vs 0.009) (Table 2).

The data source, dental records, has been shown, at least in large samples, to be suitable for monitoring time-related trends in the caries situation of children (25). Furthermore, when data in public dental records were compared with recordings based on graded caries criteria, there was no significant difference provided initial carious lesions were omitted (23).

During the early 1970s the treatment rate increased for the youngest and the oldest children, nationwide (14, 15). However, there is no information indicating a skew age distribution in the two groups which may affect the results. Moreover, the reported data of surfaces filled are weighted. Moving averages for surfaces filled accentuated the decline, but age-specific analyses have shown a minor effect of this transformation. The greatest deviation, 4.4 percentage points, was recorded for 17-year-olds in 1972 (3). Independently of moving averages, the profiles of the curves for surfaces filled or treated were similar (Fig. 2). The transformation had no impact on the variable school-based fluoride program.

The calendar year 1967 was regarded as the baseline for the dental variables for several reasons: the extraction rate due to caries was at a maximum as well as the filling rate in the north, and county-wise information on the school-based fluoride programs was available. Most of the background variables changed similarly in both groups during the period of observation. Thus the findings in Tables 4 and 5 were generally independent of whether the calendar years shown were used or other years.

Rank correlation was used to assess relationships between changes in the dental variables and time. The bivariate correlation analyses indicated significant relationships between the number of surfaces treated and some background variables (Table 4). Accordingly, an assumption for partial correlation procedures describing the relationship between 2 variables while controlling for the effect of other variables was satisfied (26). To obtain the greatest sample for multiple regression, these analyses were primarily applied for the longer periods of observation and for at most 3 background variables (26). Partial correlation rather than multiple regression analyses revealed the potentially strongest variables related to the decline. Analogous changes in most independent variables, e.g. the school-based fluoride programs, occurred in both groups. Accordingly, variables such as the fluoride programs would not be statistically related to the caries decline even though they may have contributed to it. Owing to the aggregated data, the statistical analyses are indicative of a relationship rather than explanatory.

Comments on the findings

It is claimed that the caries decline in Norway started in 1972 as a result of the release of fluoride toothpaste for over-the-counter sale in September 1971 (6–8). The decline has also been claimed to have occurred simultaneously in all parts of the country and to have been of the same magnitude (6). Our findings disprove these claims, although the same data were assessed. The decrease in treatment was significant in the north before 1972 and the decline was significantly greater in the north than in the southwest (Table 3). Although not statistically tested, an

Table 5. *P* values for partial correlation for paired differences of the sum of surfaces filled and teeth extracted due to caries[1] in 11 counties between the years 1967 and 1976 versus fluoride tablets available in 1976, school-based fluoride programs in 1972, proportion 20 years and older with senior secondary education in 1975, and inhabitants per dentist in 1978

Surfaces filled (FS)	F-tablets 1976	F-programs 1972	Education 1975	Inhabitants per dentist 1978
FS	*0.006*	Contr.	Excl.	Excl.
FS	0.021	Excl.	Excl.	Contr.
FS	0.025	Excl.	Contr.	Excl.
FS	0.016	Contr.	Excl.	Contr.
FS	0.032	Contr.	Contr.	Excl.
FS	0.044	Excl.	Contr.	Contr.
FS	Contr.	0.036	Excl.	Excl.
FS	Excl.	0.050	Contr.	Excl.

[1] Extracted teeth equal to 3 surfaces filled. Excl. = excluded, Contr. = included in the analyses.

early decline in the northern counties has been reported (5). Age-specific analyses of surfaces filled showed that the decline started at different points in time for different ages (3). Thus, several analyses indicate that the caries decline started at different times and in several counties years before fluoride toothpaste was on the market.

The caries decline in Norway may be related to several factors: the Public Dental Service, background variables, or dental variables.

The Public Dental Service. The ratio of inhabitants per dentist in the north lagged about 6–8 years behind that in the southwest in the late 1960s and early 1970s (Table 1). The ratio improved similarly in the north and southwest. Communities with inadequate dental services had priority during the implementation of the PDS. This may partly explain the increasing number of surfaces filled although the extraction rate declined in the southwest in the 1960s. According to international data, the population to dentist ratios had a limited impact on caries decline (13). This study seems to confirm that finding.

The participation of children in the school-based fluoride programs increased at about the same rate in both groups (Fig. 1). Mainly supervised brushing with fluoride solutions was implemented in these counties in the 1960s, but this was gradually replaced by the more efficient mouth-rinsing during the first half of the 1970s (21, 27). Provided the 1% level indicates significance, the fluoride programs were insignificant, while the availability of fluoride tablets in 1976 was significantly related to the caries decline (Tables 4 and 5). Few children used fluoride tablets around 1970, so this cannot account for the initial decline. On the other hand, more fluoride tablets and a tendency to more school-based fluoride programs in the north may indicate a preventive attitude in the Service. The school-based fluoride programs and an established PDS may partly explain the early decline in the north. The impact of dental health services and fluoride programs has also been considered important for the caries decline in Denmark (28). Moreover, several dental districts in southeast Norway documented caries decline related to school-based fluoride programs years before fluoride toothpaste was available (23, 27, 29–33).

Background factors. The sale of fluoride toothpaste comprised about 60% of the market in the early 1970s (Fig. 1). This estimate is supported by the self-reported use between 1973 and 1975: 58% by children aged 15 and above (34), 75% among 14-year-olds (27), and 82% among 7–15-year-olds (20). If the caries decline in Norway had been solely ascribable to fluoride toothpaste, then the declining extraction rate and the early caries decline in the north are difficult to explain. The lower level of education in the north does not match these changes. The continued decline in both groups in the 1970s, on the other hand, may be related to many factors, among them the fluoride programs, fluoride toothpaste, fluoride tablets, and improved education (3, 5, 29).

Dental variables. The dental situation was worse in the north than in the southwest in the 1960s (Fig. 2, Table 2). The extraction rate and the number of root-filled teeth indicate fairly equal criteria for treatment in the 2 groups. The criteria for filling primary carious lesions do not appear to have been changed in Norway until the late 1970s (23, 27, 29, 35, 36), when radiographic carious lesions had to be more advanced before fillings were inserted (37). Surfaces filled due to recurrent caries, filling failures, or extensions constituted about 1/3 of the number of surfaces filled in adolescents in the 1960s (24). Whether the criteria for replacement were changed during the period of observation is uncertain.

It might be argued that supervised toothbrushing with fluoride solutions 4–5 times per year would improve oral hygiene compared to fluoride mouth rinses. When the oral hygiene and gingival conditions were compared in 14-year-old children who had participated in either rinsing or brushing programs since the age of 7 years, there was no significant difference in plaque nor in gingivitis scores (27). On the other hand, DMFS scores based on radiographs showed a 31% difference in favor of the rinses, although the socio-economic conditions of the children in the two neighboring towns were similar (27). The difference was due to the filled rather than the number of decayed surfaces.

Some years after the Second World War, when caries activity in Scandinavia was very high, about 50% of fillings were inserted on surfaces recorded as carious 1–2 years earlier (38). Four fluoride applications during 1 year resulted in 40% less need for filling (38) and recurrent caries was reduced by 33% following 3 years of fluoride mouth-rinses (39). From 1967 until 1975 the caries decline was equal to 52% fewer surfaces treated in the north, compared to 38% in the southwest, i.e. equivalent to compound annual reduction rates of 9.6 and 5.5%, respectively. The 9.6% is high compared to other data from the same period (40), but may be partly explained by calculations based on surfaces treated rather than primary caries scores. For Norwegians aged 17 years the improvement until 1975 corresponded to 46 and 28 fewer surfaces treated in the north and southwest, respectively.

Conclusions

The caries decline started at different times in different parts of Norway. In the north, it started 3–4 years before fluoride toothpaste came on to the market and was greater than in the southwest. The northern counties were characterized by a higher infant mortality, a lower proportion of people having completed senior secondary education, more inhabitants per dentist, and the most unfavorable caries situation in the 1960s. About 60% of children participated in school-based fluoride programs when fluoride toothpaste became freely marketed in September 1971. More participants in fluoride programs and significantly more fluoride tablets in the north indicate a preventive attitude among dentists. The early caries decline is most likely related to the school-based fluoride

programs, whereas several factors may have sustained a continuing decline.

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Received for publication 26 June 2000
Accepted 19 October 2000